Comparative Study of the Osteoblastic Activity of Two Implant Systems (Endopore *versus* Entegra) Utilizing Single Photon Emission Computed Tomography (SPECT): Experimental Study in Pigs Model

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ABSTRACT

Implantology has been an important component of dental management for over forty years, and during that period, many configurations of implant materials and methods have been developed. As empirical and clinical research yield new implant materials, there has been need to test and compare these materials to provide the most cost-effective and efficient implants. Evaluation of efficiency of implants has relied heavily on histological and radiological methods, but these one-dimensional measurement methods fail to evaluate the osteoblastic activity and osseointegration properties of putative implants. In this report, we describe the use of a quantitative single photon emission computed tomography (SPECT) as a tool for comparing the osseointegrating capabilities of two types of implants.

Keywords: Dental implants, osseointegration, osteoblasts, single photon emission computed tomography (SPECT), tomography

Estudio Comparativo de la Actividad Osteoblástica de Dos Sistemas de Implantes (Endopore *versus* Entegra) Utilizando Tomografía Computarizada por Emisión de Fotones Individuales: Estudio Experimental en Modelos Porcinos

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RESUMEN

La implantología ha sido un componente importante del tratamiento odontológico durante más de cuarenta años, y durante ese período, se han desarrollado muchas configuraciones de materiales y métodos de implante. A medida que la investigación empírica y clínica proporciona nuevos materiales de implante, ha surgido la necesidad de probar y comparar estos materiales para lograr que los implantes sean lo más costo-efectivos y eficientes posible. La evaluación de la eficiencia de los implantes ha dependido considerablemente de los métodos histológicos y radiológicos, pero estos métodos de medición unidimensional no son útiles a la hora de evaluar la actividad osteoblástica y las propiedades osteointegradoras de los implantes putativos. En este reporte, describimos el uso de la tomografía computarizada por emisión de fotones individuales (SPECT) como herramienta para comparar las capacidades osteointegradoras de dos tipos de implantes.

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Palabras claves: Implantes dentales, osteointegración, osteoblastos, tomografía computarizada por emisión de fotones individuales (SPECT), tomografía

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INTRODUCTION

Forty years ago, the first patient was treated with osseointegrated implants by Branemark who was considered the father of osseointegration. In the years since then, the original idea of osseointegration has been modified through empirical research and a great deal of careful, laborious work, from which have emerged the various implant systems as well as the basic principles of implantation in the oral cavity (1). Clinical research has continued to validate and improve the science of implantology; however, most of the experimental work on osseointegration has utilized histological, histomorphometric and radiological methods in the evaluation of peri-implant bone changes. More recently, Khan and co-workers developed a quantitative single photon emission computed tomography (SPECT) as a tool in the evaluation of the integration process of endosseous dental implants (2). The use of SPECT has introduced a more precise and quantitative approach to the evaluation of new bone regeneration.

The Endopore dental implant incorporates a unique design that uses a multi-layer porous surface geometry over most of its length to achieve integration. It was designed because of the need for a simple, less invasive and biologically more compliant system. The Endospore system uses an approach that has been exploited extensively since the mid-1980s for orthopaedic joint replacement fixation, and has enjoyed outstanding success rates (3–10). In contrast, a screw-type implant is stabilized only by the alveolar crest's superior and inferior bone cortices and over most of its length by weak cancellous bone. With threaded implants, the fixation that occurs at the bone implant interface can allow for rotational movement of the implant, which could impede bone regeneration (9).

Clinical, radiographic and histological examinations have demonstrated repeatedly that Endopore delivers shorter initial treating periods and simpler surgical techniques than are customary with other implant designs. The literature is replete with proven histological and clinical success of Endopore and other porous surfaced implants (3–10). Unfortunately, information from most clinical observations or conventional views is usually only sufficient for diagnosis, but accurate quantitative analysis is not always possible because of interference from superimposed structures (11, 12).

Reports in the medical literature on the radiological evaluation of peri-implant changes in the context of osseointegration were initially limited to one-dimensional quantitations of height of the defect (4). Although digitized radiography and computed tomography can facilitate quantification of bone changes, these methods generally reflect morphologic changes but often fail to detect the dynamics of osteoblastic activity (13–16); however, bone scintigraphy has been shown to accurately reveal osteoblastic activity (17, 18). Single photon emission computed tomography provides an additional refinement to planar imaging and permits accurate quantitations common to most tomographic techniques by removing regions which are not of clinical interest. Single photon emission computed tomography has been used successfully for clinical studies of many organ systems including the skeletal system (16–19), however, SPECT has not so far been utilized for the comparison of the porous-coated and the threaded implants.

In this report, we present evidence obtained from quantitative SPECT suggesting that there is little difference in bone regeneration between the porous surface and screw type implants.

MATERIALS AND METHODS

A six-month old female pig weighing 23 kg was chosen for the study. The pig was pre-anaesthetized with azaperone (Stresnil,) and butophanol at the dose rates of 6 mg/kg and 0.2 mg/kg, respectively, induced with 5% thiopentone at 10 mg/kg, intubated and maintained with isofluorane in oxygen. An Omicron Plus Multiparameter monitor was used to evaluate the vital parameters including electrocardiogram (ECG), heart rate, pulse rate, invasive arterial blood pressure, respiratory rate, pulse oximeter oxygen saturation ($Sp0_2$), and end tidal carbon dioxide (CO_2).

Single photon emission computed tomography imaging was performed at 11 weeks and four days (81 days) after surgical immediate implantation of Endopore (porous-beaded) and Entegra (screwed) implant into the fresh extraction socket in the right side and left side of the mandible, respectively of an experimental pig. To ensure uniformity, each implant was placed in the canine region of the mandible. At 81 days post implantation, the pig was anaesthetized and given an intravenous injection (into the ear vein) of $740MB_q$ (20 mci) technetium 99m methylene diphosphate. The pig was subsequently euthanized two and half hours after the injection and then the mandible was removed. Tomographic images of the mandible in the region of interest were acquired within 30 minutes of removal, using a Semens Orbiter II rotating large field-of-view gamma camera equipped with a low energy high resolution collimater (Siemens Medical System Inc, Erlangan, Germany). A total of 64 projection images (205/images) were acquired over 180 degrees in a 128 by 128 matrix with a dedicated nuclear medicine computer (Siemens ICON computer).

The projection data were corrected for flood field non-uniformity and centre of rotation. Transverse re-construction was then performed with a Shepp-Logan Hanning filter cut-off frequency of 0.4. By utilizing the transverse slices, the osteoblastic activity in the jaw at the sites of immediate implantation was observed and calculated. The activity of the Endopore implant was compared with that of the Entegra implant. Each was also compared with a reference point within the jaw on each side, using the average count (pixel) for each area of interest.

RESULTS

The SPECT images demonstrated increased osteoblastic activities on both sides of the jaw in the region of interest as shown in Figs. 1 and 2. The osteoblastic activity on the side

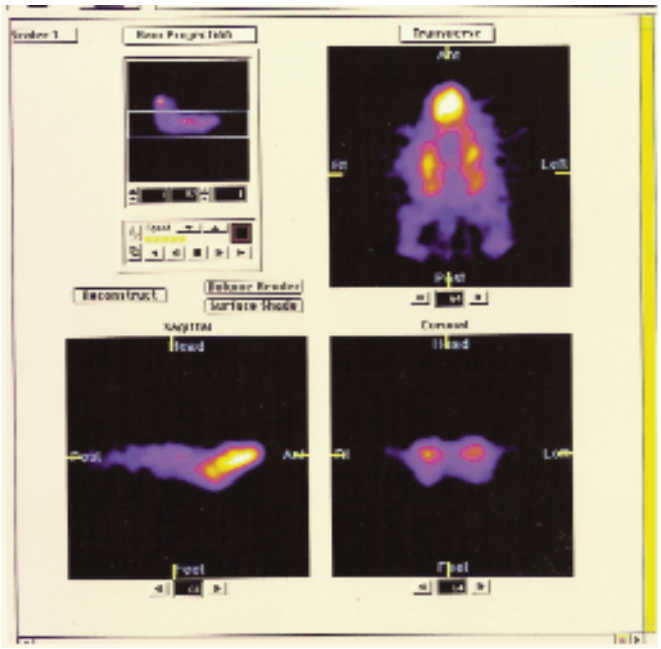

Fig. 1: Comparative osteoblastic activity for Endopore (right side) and Entegra (left side).

which had the Endopore implant was similar to the osteoblastic activity on the side with a longer Entegra implant. The average count was 21.7 cts/pixel and 21.8 cts/pixels, respectively (Fig. 3) with a calculated relative activity ratio of 1:1.

DISCUSSION

The Endopore dental implant incorporates a unique truncated core-shaped design that uses a multi-layered porous surface geometry over most of its length to achieve integration by three-dimensional bone in-growth. It was designed because of the need for a simpler, less invasive and biologically more compliant system. It employs the approach that has been used extensively for orthopaedic joint replacement fixation since the 1960s. The Endopore implant has outstanding suc-

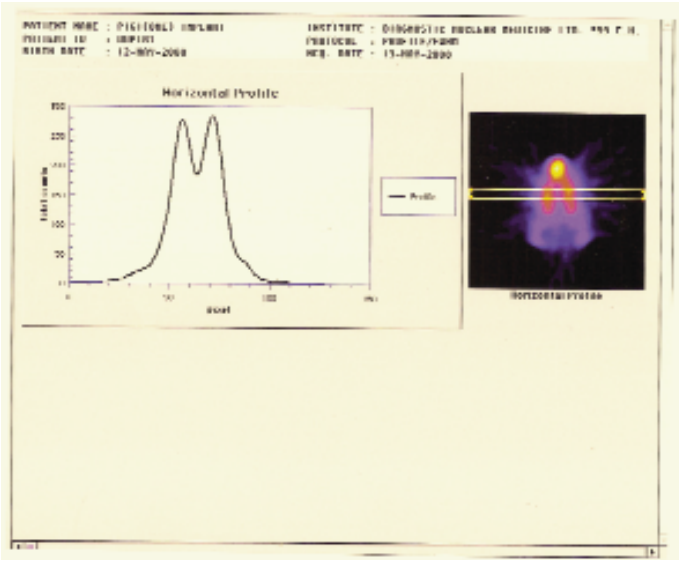

Fig. 2: Activity curve and ratio between the two implant systems.

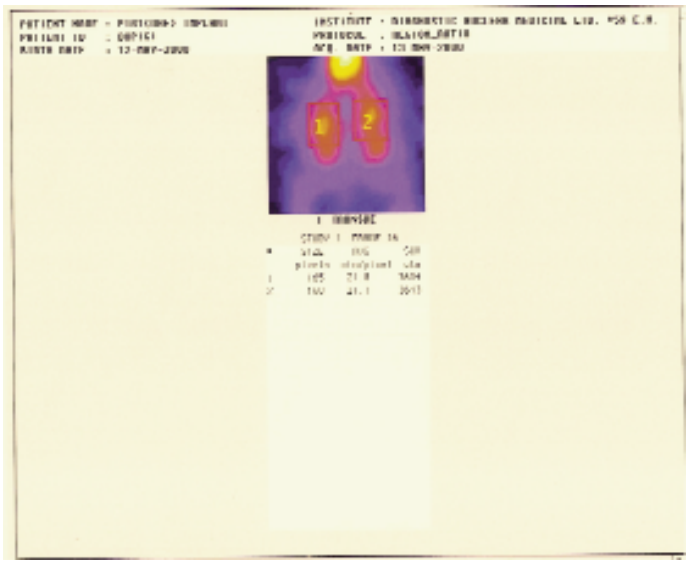

Fig. 3: Average count of each implant system.

cess rates documented. The strong foundation of Endopore's high success rate is the engagement of the alveolar crest by cortical bone in-growth into the implant's interconnecting pores. When this implant is placed into function, occlusal loads transferred to the crest stimulate further cortical bone development in accordance with Wolff's law. In contrast, a screw-type implant is stabilized only by the alveolar crest's superior and inferior bone cortices and over most of its length by weak cancellous bone. With threaded implants, the fixation that occurs at the bone implant interface can allow for rotational movement of the implant.

Clinical, radiographic and histologic examinations have documented repeatedly that Endopore, the world's shortest implant, delivers shorter initial treating periods and

simpler surgical techniques than are customary with other implant designs. As such, the literature is replete with the proven histological and clinical success of Endopore implants and porous surface implants (3–10).

Threaded implants have been compared with porous surfaced implants for implant stabilization in bone – endodontic implant model (11). Also, histological comparisons of porous-coated *versus* threaded dental implant have been documented in the literature (8). In the present study, we used SPECT to evaluate and compare the osteoblastic activity and consequent osseointegration of two implant systems: the Endopore (porous-beaded) and Entegra (screwed) implants systems. Single photon emission computed tomography displayed that the osteoblastic activity of a shorter Endopore implant was actually the same as that of a longer Entegra implant at 11 weeks and four days. It will be interesting to find out the comparative osteoblastic activity of these two implant systems at three months (recommended time for loading of the Endopore implant system) and at six months (the recommended time for the loading of the Entegra implant system).

The SPECT technique uses a radio-pharmaceutical agent such as technetium 99m which contains a single gamma-photon-emitting radionuclide. When injected intravenously, it is possible, by using radiation detectors, to obtain a three-dimensional representation of the distribution of radioactivity within an organ or region of interest in which the radio-pharmaceutical is localized (16). Consequently, SPECT has the unique ability to quantitate physiologic events such as osteoblastic activity by using a bone-seeking radio-pharmaceutical. This is what has made SPECT outstanding when compared to other tomographic techniques, such as computed tomography which basically does not provide functional or physiological data.

It is reasonable to extrapolate that the implant with more osteoblastic activity (Endopore) has better osseointegration with the surrounding bone than the threaded implant (Entegra). As such, it is important that other researchers testing the osseointegration capabilities of implants and comparing them with one another not limit their research modalities to clinical, radiographic and histologic/histomorphometric approaches, but should consider SPECT, a novel approach that has the virtue of imaging bone changes dynamically while additionally offering an objective method for monitoring such changes before, during and after implantation. Recently, Ogunsalu *et al* utilized this technique of SPECT to validate a new technique of implantation of the sandwich unit for the closure of an oro-antral communication (19).

CONCLUSION

The Endopore dental implant (one of the world's shortest implants) has greater osteoblastic activity and hence better osseointegration than the Entegra (threaded) dental implant. Single photon emission computed tomography is very valuable in assessing and comparing osseointegration of implant systems. It must be utilized by clinicians and manufacturers to compare the various emerging implant systems with one another.

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